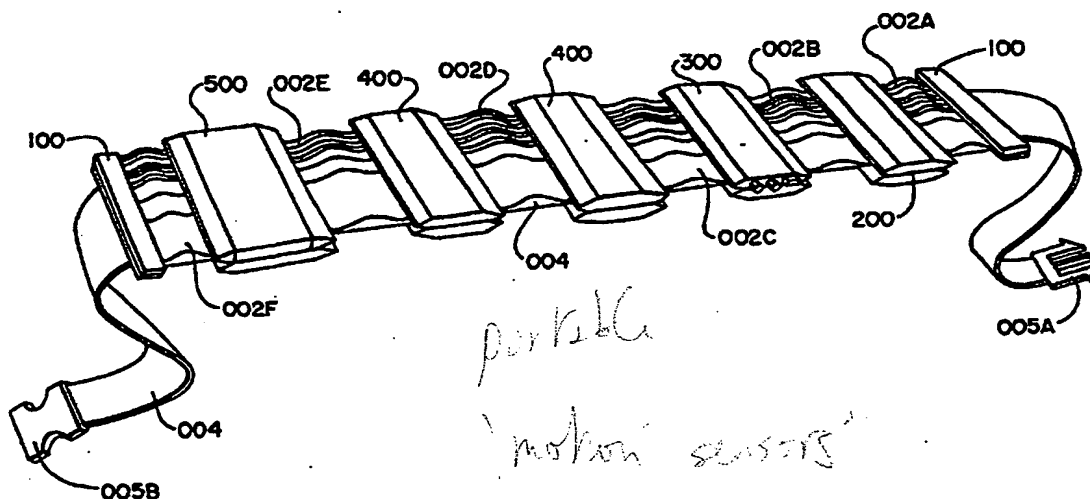




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(54) Title: FLEXIBLE WEARABLE COMPUTER



## (57) Abstract

A flexible wearable computer in the form of a belt comprising, in combination, elements for computing comprising a microprocessor module (200), a RAM-I/O module (300), a plurality of mass memory modules (400), a power supply module (500), and a plurality of bus termination modules (100) operationally associated with a plurality of flexible signal relaying means. The computing elements are mechanically associated with a flexible non-stretchable member (004), and a protective covering means (006). The flexible non-stretchable wearable member (004) is secured around various parts of the body. An input and output device (060) is connected to the flexible wearable computer (004) by the I/O bus (061) attached to the output and input ports (326) and (327), respectively.

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## FLEXIBLE WEARABLE COMPUTER

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### FIELD OF THE INVENTION

This invention relates generally to the field of portable computers, and more specifically to a flexible, wearable computer that can be worn on the body and repeatedly bent in an infinite number of planes without failure of operation.

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### DESCRIPTION OF RELATED ART

#### Definitions

A computer system is defined as comprising three basic components: an input device, an output device and a computer. A computer is defined as comprising memory, a processor, and associated support circuitry and components. Memory comprises main memory which is volatile, and mass storage memory which is usually nonvolatile. A portable computer system is one that the user can easily carry around. Throughout this text the author will refer to a computer to mean only and specifically the main and secondary storage memory, the processor, and a power supply. The author will also use volume to characterize both the size and the mass of computers. This is because the overall density of

30

silicon-based computers is asymptotic to a constant. Therefore, volume will necessarily indicate a maximum weight.

#### Integration

5           Small and therefore portable computers have resulted from the intersection of innovations and inventions across a wide variety of domains and fields including the arts of silicon manipulation, and mechanical and electrical design, and component integration. Integration is the process of decreasing the size of and the space between electrical  
10 elements, and it has been the pathway to power reduction and speed. But size reduction accrued benefits independent of processing power. Computers that once required buildings to house and small power plants to run can now be comfortably lifted with one hand. Since integration and therefore miniaturization has brought nearly all of the advances in service  
15 levels to date, it is the major force in the creation of the prior art in portable computing and the direction of future advancement for computer construction in general.

          There has been tremendous innovation and invention using integration as a means of making computers portable. Computers are  
20 available that are small enough to be lifted by one finger. The result has been explosive demand for portable computing devices. Dataquest predicts that by 1994 sales of portable computing devices will be well over \$13 billion (Byte, volume 16, number 11, p. 194).

          "Picocomputers" are the state of the art of integration as a means of  
25 creating portable computers (New York Times, March 23, 1992). Inventors such as M. E. Jones, Jr. have developed a single chip that contains all of the elements needed for a computer. This has allowed creation of computer systems that can fit in the breast pocket of a man's jacket and run for 100 hours on a conventional flashlight battery. The major limitations of these  
30 computer systems is that they have very small amounts of memory greatly limiting the usefulness of the device for tasks to which most

computer users are accustomed. They also have very small input and output devices which are slow and inconvenient to use.

#### Useful Portables

5        Other innovations include computers with increased processing abilities that must be carried with one hand. These rigid rectilinear-shaped devices fall into the classes lap-top, palm-top or hand-held computers and increase the processing and memory capacity of the  
10        picocomputer by including the required processors and memory power in a larger enclosure. For the episodic portable computer user that spends little time actually carrying these devices, these rigid rectilinear devices provide high levels of service rivaling desk-top micro and  
15        minicomputers. For the intensive user that processes large amounts of data and must also carry the computer for long periods of time, these devices have several disadvantages.

      First, research has shown that people carrying these computers for long periods of time are prone to flexi carpi ulnaris tendonitis which can be painful and debilitating. This affliction is due to prolonged and simultaneous clenching of the fingers and flexing of the wrist, an action  
20        unavoidable when carrying these devices.

      Second, for intensive data acquisition applications, size once again is a constraint. The amount of secondary memory required for implementation makes this option impractical for portable computers in rigid rectilinear packaging. On-board memory requirements have been  
25        sidestepped by including wireless data links to a host computer for downloading data. However, these options are very costly, up to the cost of the computer itself, and increase the volume of the devices by as much as a factor of two. Furthermore, wireless communication is presently a very slow data transfer process.

30        Third, field service research for Rockwell International has demonstrated that user compliance of rigid rectilinear hand-carried and hand-held computers is low, and gets lower as the size of the device

increases. Field service personnel expressed considerable displeasure with having to lug a "brick" around during the execution of their task. Most notably it restricted the use of their hands by virtue of one, or both being used to carry the computer.

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#### Wearable Portables

There has been innovation and invention to harness rigid rectilinear computers on various parts of the body. Reddy Information Systems, Inc. has produced a computer called Red Figure 1 that has a head  
10 mounted output device (A) from Reflection Technologies called the Private Eye, and a belt-mounted rigid rectilinear-packaged computer and input device (B) secured by a belt harness (C) (New York Times, March 29, 1992). Infogrip Inc. and Select Tech Inc. have combined technologies to produce the Hip Pc in a similar configuration.

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There are two main disadvantages to this approach. First, harnessing a rigid rectilinear-packaged computer anywhere on the body creates an uneven load on the spine. Prolonged wearing of such devices creates strain in the supporting muscles opposite the place where the computer is harnessed. Second, these configurations do not allow the  
20 human body to comfortably contact a firm surface. The rigid rectilinear computer on a harness or belt is literally a lump on the surface of the body. Lastly, rigid rectilinear designs are inherently limited in expandability. To increase processing power, hardware size must be increased. There is a volume limit beyond which the computer is no longer portable.

25

There has been innovation and invention to make computers more comfortable to wear. Hideji Takemasa of NEC Corp. has created a variety of rigid curvilinear-packaged computer models that conform to various parts of the body (Figure 2) (Fortune, January 13, 1992). These devices include a processor and CD-ROM reader (D), and a fold out input/output  
30 device (E, F). Although aesthetically more appealing than the rigid rectilinear lumps of the Red and Hip PC models, the NEC models nonetheless suffer the same disadvantages. The NEC curvilinear designs

are rigid and dynamically nonconforming and subject the spine to uneven loading. They also do not allow comfortable contact of the human body with firm surfaces. Furthermore, these rigid, curvilinear designs must be made in many sizes since it is technically impossible to make one of these designs fit all human morphologies. They are also inherently limited in expandability just as the rigid rectilinear designs.

### SUMMARY OF INVENTION

The present invention exemplifies a new and unobvious art of a flexible wearable computer. Briefly and generally, the flexible wearable computer comprises a microprocessor, memory, an input/output controller, and a power supply operably associated with one another through a flexible signal relaying means. The assembly is supported by a tensile load bearing means and protected by a compressive load bearing means. The microprocessor, memory, input/output controller, and power supply are mechanically associated in a module assembly such that the flexible wearable computer can bend in an infinite number of planes without failure of operation.

#### 20 Objects and Advantages

An important advantage of the flexible wearable computer is that it will always provide greater utility than rigid designs for those users that must carry their computer around while processing large amounts of data, regardless of the state of the art of integration and miniaturization. That is, regardless of how much computer power can be delivered in a given rigid package, providing a flexible wearable computer allows more of that computer power to be comfortably carried by the user. For example, even if a Cray supercomputer can be reduced to the size of a wristwatch, the intensive computer user will find more utility in a flexible computer that is an array of the microprocessors in the wristwatch-sized Cray that is fashioned for instance as a comfortable vest.

This relationship can be mathematically demonstrated with a common market model adapted for computer power demand. Refer now to equation (1)

$$Q = c - aP + bS \quad (1)$$

5 where,

Q = total amount of computers demanded in a specified context;

P = the price of computers sold in the marketplace for that context;

S = the service level provided by computers in that context.

10 The service level of a computer for any specified context is related to the number of useful operations per second (UOPS). This value is driven by several factors including the elegance of the program, memory size and access time, and raw processing speed. Service level is also related to volume. Volume is less critical when a user does not need to carry the computer. It becomes a major determinant when a user must be  
15 ambulatory while using a computer.

Service level can be defined as

$$S = \frac{\text{UOPS}}{V_H} \frac{F}{\text{person}} \quad (2)$$

20 where,

F = min {V<sub>H</sub>, V<sub>I</sub>};

V<sub>H</sub> = volume of the hardware;

25

$\frac{\text{UOPS}}{V_H}$  = power density and is roughly constant.  
That is, the greater the UOPS, the larger the volume of the hardware.

30

V<sub>I</sub> = the constrained volume of user interface, that is, the largest hardware volume the user can employ to accomplish a specific computing task;

35

person = the number of individuals that must use the hardware.

For the majority of computing applications volume is irrelevant. Equations (1) and (2) mathematically describe this observation. In these



contexts, the user is unconstrained by the volume of the hardware, and  $V_I$  is infinity making  $F$  equal to  $V_H$ . Volume hence has no influence on the service level (5) and therefore no influence on the quantity (2) of computers demanded.

5        However, for users that desire to or must carry a computer around, the volume of the hardware becomes critical. Equations (1) and (2) mathematically describe this observation also. There exists for any rigid form factor a maximum volume ( $V_I$ ) beyond which the user cannot carry a computer. ( $F$ ) is then equal to ( $V_I$ ). Hence, increasing the power density  
10    is the only means to increase service level and therefore quantity demanded.

Now it is clear from equation (2) that if  $V_I$  can be increased,  $V_H$  can also be increased thus increasing the UOPS obtainable. This can be done without increasing power density. The flexible wearable computer directly  
15    increases  $V_I$  compared to rigid packaging schemes because it allows hardware to be shaped like articles of clothing allowing the more comfortable placement of larger volumes of hardware on various areas of the body. It obviates the need to carry the entire hardware in one or both hands. It also eliminates the uncomfortable nature of strapping a rigid  
20    device onto one aspect of the body. It also eliminates the need to make a variety of sizes such as the rigid curvilinear designs require.

Another advantage of the flexible wearable form factor is that by implementing a computer as many small rigid elements instead of one large rigid element, the bending moment across each element is smaller  
25    since the area of each element is decreased. The bending moment is caused when a rigid element is worn against the body and the body comes into contact with any firm surface. Distributed or concentrated loads are applied normal to the surface of the element. An example would be when a wearer sat down in a chair. The firm elements of the chair would exert  
30    forces against the rigid elements.

Further objects and advantages of the present invention include:

- (a) To provide a flexible wearable computer that can be shaped into a limitless variety of shapes and sizes.
- (b) To provide a flexible wearable computer that can accommodate a wide variety of human morphologies.
- 5 (c) To provide a flexible wearable computer that allows comfortable hands-free portability.
- (d) To provide a flexible wearable computer that symmetrically distributes its volume and therefore evenly loads the spine.
- (e) To provide a flexible wearable computer that eliminates flexi carpi  
10 ulnaris tendonitis.
- (f) To provide a flexible wearable computer that is comfortable to wear while the human body is against a firm surface.
- (g) To provide a flexible wearable computer that increases the compliance of field service users by allowing hands-free portability  
15 without sacrificing comfort.
- (h) To provide a flexible wearable computer whereby the computer can be more comfortably carried and operated than an integrated computer of comparable processing power in a rigid rectilinear or curvilinear packages.
- 20 (i) To provide a flexible wearable computer with data transfer rates that are faster than wireless communication systems.
- (j) To provide a flexible wearable computer that can more easily and comfortably be expanded than rigid package designs.
- (k) To increase the ruggedness of a wearable computer by decreasing the  
25 size and thus the bending moment across any rigid elements.

Other objects and advantages of the present invention and a full understanding thereof may be had by referring to the following detailed description and claims taken together with the accompanying illustrations. The illustrations are described below in which like parts are  
30 given like reference numerals in each of the drawings.

### Drawing Figures

Figure 1 is a perspective view of the prior art of a wearable portable computer system produced by Reddy Information Systems called Red.

Figure 2 is a perspective view of the prior art of a wearable portable computer system by Takemasa of NEC Corporation.

Figure 3 is a view of a user wearing the preferred embodiment of the flexible wearable computer system which by definition includes an input/output device.

Figure 4 is a view of a user wearing the flexible wearable computer system with the outer sheath ghosted.

Figure 5 is a perspective view of a preferred embodiment of the flexible wearable computer which by definition does not include the input/output device.

Figure 6 is a perspective view of the flexible wearable computer showing the surface that contacts the body with the outer sheath partially removed.

Figure 7 is a perspective view of the flexible wearable computer with the outer sheath completely removed.

Figure 8 is a perspective exploded assembly view of a microprocessor module.

Figure 9 is an orthographic cross sectional view of the microprocessor module.

Figure 10 is a perspective exploded assembly view of the RAM-I/O module.

Figure 11 is a perspective exploded assembly view of the mass memory module.

Figure 12 is a perspective exploded assembly view of the battery module.

Figure 13 is an exploded assembly view of the bus termination module.

Figure 14 is a perspective view of an alternative embodiment of the flexible wearable computer in the form of a vest.

Figure 15 is a perspective view of the alternative embodiment in the form of a vest with the outer sheath ghosted.

Figure 16 is a rear perspective view of the alternative embodiment in the form of a vest with the outer sheath ghosted.

5        Figure 17 is a schematic perspective view of the user wearing the flexible wearable computer system in the form of a vest with a touch sensitive flexible LCD output device worn wrapped around the forearm.

10       Figure 18 is a schematic perspective view of the user wearing the flexible wearable computer system in the form of a belt with a hand-mounted free-space pointer input device.

Figure 19 is a schematic perspective view of the user wearing the flexible wearable computer system in the form of a belt with a tethered infra-red transceiver worn on the shoulder.

15       Figure 20 is a schematic perspective view of the user wearing the flexible wearable computer system in the form of a belt with a wireless infra-red transceiver communication link between the belt and a hand held pen based display device.

20       Figure 21 is a schematic perspective view of the user wearing the flexible wearable computer system in the form of a vest with a wireless infra-red transceiver communication link between the vest and a heads-up display.

Figure 22 is a schematic perspective view of the user wearing the flexible wearable computer system in the form of a vest with a projection display mounted to it.

25       Figure 23 is a schematic perspective view of the user wearing the flexible wearable computer system in the form of a headband with a heads-up display mounted to it.

30       Figure 24 is a schematic perspective view of the user wearing the flexible wearable computer system in the form of a belt with a split QWERTY keyboard input device mounted to it.

Figure 25 is a schematic perspective view of the user wearing the flexible wearable computer system in a form that wraps around the forearm.

5 Figure 26 is a schematic perspective view of the user wearing the flexible wearable computer system in the form of a vest with a heads-up display mounted in the breast area.

Figure 27 is a schematic perspective view of the user wearing the flexible wearable computer system in the form of a vest with an ear clip speaker and microphone input/output device tethered to it.

10 Figure 28 is a schematic perspective view of the user wearing the flexible wearable computer system in the form of a garment with motion sensors integrated into the garment.

Figure 29 is a schematic perspective view showing the computer in a totally hands-free operation.

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#### Drawing Reference Numerals

- A Reflection Technologies Private Eye wearable display
- B Reddy Information Systems 1 ) 05 rigid rectilinear personal computer and RAM card reader
- 20 C Padded harness
- D NEC Corporation's personal computer and CD-ROM reader
- E NEC Corporation's input device
- F NEC Corporation's output device
- 002a Flexible circuit
- 25 002b Flexible circuit
- 002c Flexible circuit
- 002d Flexible circuit
- 002e Flexible circuit
- 002f Flexible circuit
- 30 004 Tensile load strap
- 005a Belt latch, male
- 005b Belt latch, female

- 006 Foam sheath
- 010 Module recess
- 011a Eyelet snap
- 011b Eyelet snap
- 5 046 Seam surface
- 060 Portable input/output device
- 061 I/O bus
- 100 Bus termination module
- 112 Bus termination resistors
- 10 114 Bus termination printed circuit board
- 115 Bus termination module solder pins
- 116 Bus termination plated via holes
- 200 Microprocessor module
- 212 Microprocessor
- 15 212a Microprocessor support components
- 214 Microprocessor printed circuit board
- 215 Microprocessor printed circuit board solder pins
- 216 Microprocessor plated via holes
- 217 Microprocessor module top shell
- 20 218 Microprocessor module bottom shell
- 219 Microprocessor module boss
- 219 Microprocessor module boss
- 220 Holes for microprocessor module assembly
- 222 Microprocessor module retention plate
- 25 223 Microprocessor module self tapping screw
- 300 RAM-I/O module
- 314 RAM-I/O printed circuit board
- 317 RAM-I/O module top shell
- 322 RAM-I/O module retention plate
- 30 323 RAM-I/O port bezel
- 324 Random access memory chips
- 325 RAM-I/O Module orifice

- 326 Output device port
- 327 Input device port
- 328 Communications port
- 347 Input/output processor
- 5 347a Support circuitry components
- 400 Mass memory module
- 412 Flash memory chip
- 414 Mass memory circuit board
- 417 Mass memory module top shell
- 10 500 Battery module
- 508 Battery bezel
- 514 Battery module printed circuit board
- 517 Battery module top shell
- 523 Battery module self tapping screw
- 15 530 Battery cartridge
- 531 Battery fixture
- 533 Voltage regulation components

#### DESCRIPTION OF PREFERRED EMBODIMENTS

- 20 Referring now to the drawings, with particular attention to Figures 3-4. The method of using the flexible wearable computer is straightforward. The user adjusts the flexible wearable computer to fit comfortably around the waist by varying the connection of male and female belt latches 005a, 005b to a flexible tensile load strap 004. An
- 25 input/output device 060 is a pen based liquid crystal display device that has a clip allowing easy attachment to a flexible compressive foam sheath 006 when not in use. The input/output device is connected to the processor and mass memory by an I/O bus 061.

- Figure 5 demonstrates the detail of a preferred embodiment. The
- 30 computer is entirely encased in foam sheath 006 injection-molded out of antimicrobial microcellular polyurethane foam (such as Poron, available from Rogers Corporation), and varies in thickness from 0.140 inches thick

to 0.250 inches thick, and is approximately 15.0 inches long. Flexible compressive foam sheath 006 necks (narrows) down at each end such that the opening in foam sheath 006 is the same width as tensile load strap 004. Tensile load strap 004 is a belt strap consisting of woven aramid fibers (otherwise known as Kevlar, available from Dupont), but could consist of common nylon strapping or thin steel stranded cables. Tensile load strap 004 is approximately 2.0 inches x 0.02 inches x 47.0 inches. A port bezel 323 is adhered to foam sheath 006 with adhesive. It allows output device port 326, input device port 327, and communications port 328 to be exposed through foam sheath 006. A battery bezel 508 is adhered to foam sheath 006. Port bezel 323 and battery bezel 508 are all injection-molded out of ABS plastic.

Figures 4 and 7 demonstrate the structure beneath foam sheath 006 of the preferred embodiment. Five different types of modules 100, 200, 300, 400, 500 are electrically connected to each other by polyamide (Kapton, available from Dupont) flexible circuits 002a, 002b, 002c, 002d, 002e, 002f. Each computer component module 100, 200, 300, 400, 500 is affixed to the tensile load strap 004. The two-part belt latch 005a and 005b is connected to each end of tensile load strap 004.

Referring now to Figure 6, the flexible wearable computer is demonstrated with foam sheath 006 partially open revealing a molded-in module recess 010 which is approximately 0.125 inches deep. Each module 100, 200, 300, 400, 500 is seated in a separate module recess 010. Fig. 6 also reveals that foam sheath 006 is fastened to tensile load strap 004 by a pair of eyelet snaps 011a and 011b, located at both narrowed ends of foam sheath 006. Seam surfaces 046, which run the bottom length of foam sheath 006, are fastened to each other with adhesive.

#### Microprocessor Module

Referring to Figure 8, the microprocessor module 200 is demonstrated. Microprocessor 212 and microprocessor support components 212a are of surface mount size, and are soldered to a



microprocessor printed circuit board 214. The dimensions of microprocessor printed circuit board 214 are approximately 2.25 inches x 1.55 inches x 0.06 inches. At each of the long edges of microprocessor printed circuit board 214 are an array of microprocessor printed circuit board solder pins 215 which register with a corresponding array of plated via holes 216 on flexible circuit 002b. Solder pins 215 are soldered into plated via holes 216. Flexible circuit 002b and microprocessor printed circuit board 214 are sandwiched between a microprocessor module top shell 217 and microprocessor module bottom shell 218. Flexible circuit 002b is approximately 2.65 inches long x 2.00 inches wide x 0.006 inches thick. Microprocessor module bosses 219 extend from the microprocessor module top shell 217 through holes 220 in flexible circuit 002b and microprocessor printed circuit board 214. The mechanical registration and therefore electrical connection of plated via holes 216 with solder pins 215 is held true by bosses 219.

Microprocessor module top shell 217 and bottom shell 218 are shown in cross-section in Figure 9 as having approximately a 0.10 inch radius edge detail curving away from flexible circuit 002b. This feature provides a limit on the radius of curvature experienced by flexible circuit 002b. Tensile load strap 004 is fastened against microprocessor module bottom shell 218 by microprocessor module retention plate 222 and self-tapping screws 223. Self-tapping screws 223 fasten the entire assembly together by screwing into bosses 219 on microprocessor module top shell 217.

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#### RAM-I/O and Mass Memory Modules

Figure 10 demonstrates RAM-I/O module 300. It has the same basic construction as microprocessor module 200 except for two differences. First, instead of a microprocessor, random access memory chip 324 and input/output processor 347 and support circuitry components 347a, are soldered onto RAM-I/O circuit board 314. Second, output device port 326, input device port 327, and communications port 328 are electrically

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connected to RAM-I/O printed-circuit board 314, and extend through RAM-I/O module orifice 325 in RAM-I/O module top shell 317. Flexible circuit 002c is registered and fastened against RAM-I/O printed-circuit board 314 the same way as with the previously described microprocessor module 200. RAM-I/O module 300 is also connected to tensile load strap 004 in the same way as in previously described microprocessor module 200.

Figure 11 demonstrates mass memory module 400. Multiple mass memory modules are shown in a preferred embodiment and are identical except for their software addresses, and have the same basic construction as microprocessor module 200 except for two differences. First, instead of a microprocessor, flash memory chips 412 (of which there are four) are soldered to printed-circuit board 414. Flexible circuits 002d, 002e are registered and fastened against printed-circuit board 414 the same way as in previously described modules 200. Mass memory modules 400 are also connected to tensile load strap 004 in the same way as in previously described module 200.

#### Battery and Bus Termination Modules

Figure 12 demonstrates a battery module 500 containing a battery cartridge 530 held by a battery fixture 531, and a battery module top shell 517. Battery fixture 531 is fastened onto a printed-circuit board 514 with a screw 523. Voltage regulation components 533 are of surface mount size, and are soldered to printed-circuit board 514. Flexible circuit 002f is registered and fastened against printed-circuit board 514 the same way as in previously described module 200. Module top shell 517 and module bottom shell 518 are fastened the same way as in previously described module 200. Battery module 500 is also connected to tensile load strap 004 in the same way as in previously described module 200.

A bus termination module 100 is shown in Figure 13. Bus termination resistors 112 are of surface mount size and soldered to a bus termination circuit board 114. Bus termination circuit board 114 measures

approximately 2.00 inches x 0.30 inches x 0.06 inches. Bus termination circuit board 114 has an array of bus termination module solder pins 115 along one long edge which register with bus termination plated via holes 116 on flexible circuit 002f. Flexible circuits 002a and 002f measure  
5 approximately 1.5 inches long x 2.00 inches wide x 0.006 inches. Bus termination module 100 is connected to tensile load strap 004 in the same way as in previously described module 200.

### Summary, Ramifications and Scope

10 Accordingly, the reader will see that the flexible computer has the advantage of increasing the service level of portable computer hardware while also increasing the comfort of using the hardware. In addition, the flexible wearable computer has the advantages of:

- accommodating a wide variety of human morphologies;
- 15 • allowing hands-free carrying and operation;
- allowing the user to comfortably sit or lie while wearing the device;
- allowing the weight of the computer to be symmetrically distributed on the body;
- 20 • eliminating the muscle and tendon strain associated with carrying rigid rectilinear computers;
- increasing the compliance of field service personnel that must use a computer;
- allowing significantly larger amounts of secondary flash  
25 memory to be comfortably carried by the user;
- allowing expansion more easily and comfortably than rigid designs; and
- increasing the ruggedness of a mobile wearable computer by decreasing the area of the rigid elements, thereby decreasing  
30 the bending moment across each element.

Although the description above contains many specificities, these should not be construed as limiting the scope of the invention, but merely

providing illustration of some of the presently preferred embodiments of this invention. The flexible wearable computer could be implemented in many different ways. For example, each module could be potted with a solid thermoset plastic rather than have a two part shell. The flexible  
5 tensile load bearing means could consist of individually twisted aramid fibers encased in the potting compound. The flexible tensile load bearing means could be fibers woven into cloth or even a homogeneous thin layer of material. The flexible signal relaying means could be glued or otherwise permanently attached to the tensile load bearing means.

10 Components and support circuitry need not be surface mount size and soldered. The components may be affixed to the circuit board with conductive epoxy. The computer may be made even thinner and more flexible by implementing it using chip-on-board manufacturing technology. Each integrated circuit would be bonded directly to a small  
15 printed circuit board and the terminals would be electrically connected to the board. Each IC would be covered with an epoxy dab. Each discrete circuit board module could be as small as a 0.5 square inch.

The computer could be implemented as one long multi-layer polyamide flexible, or rigid-flex, circuit board. As an entirely flexible  
20 board, the module shells would rigidify the areas populated with electronic components. As a rigid-flex design, the sections with electronic components would be laminated with rigid fiberglass board stiffeners.

The flexible signal relaying means, the length of which between any two computing elements is greater than the length of the wearable  
25 member between any two computing elements, could be discrete wires or discrete non metallic filaments. It could be produced with ink traces or any type of non-metallic, flexible conductive material. The computer could be implemented as a fiber optic device. The flexible circuit could be optical fiber filaments instead of metallic or non-metallic conductors.  
30 Also, the flexible signal relaying means could be an easily detachable and re-attachable bus that is disposable.

Furthermore, the configuration of the flexible wearable computer need not be in a belt. The module and bus assembly can be fashioned in a variety of ways. Figure 14 demonstrates an alternative embodiment of the flexible wearable computer in the shape of a vest for increasing the number of elements for computing. Figure 15 shows the foam sheath of the vest removed revealing an increased number of modules. Figure 16 demonstrates the bus arrangement to accommodate the increased number of modules thereby greatly expanding the memory and processing capacity of the flexible wearable computer.

Referring now to Figure 17, the computer is shown there in the form of a vest. The output device is a touch sensitive flexible LCD 534 worn on the forearm. The wearer controls the computer by touching virtual graphical elements on the LCD with the right hand. There is an infra-red wireless data link between the computer and the LCD via infra-red transceivers 535 and 536.

Figure 18 demonstrates a configuration with the computer in the form of a belt, a free-space pointer input device 537 and a Private Eye heads-up display 538 as the output device. A free-space pointer, such as a GyroPoint, translates relative three-dimensional motion of the hand into digital pulses which are monitored by the computer. Software drivers translate the digital pulses into corresponding movements of the cursor in the virtual screen generated by the heads-up display. Both the free-space pointer 537 and the heads-up display 538 are functionally connected to the computer via tethers 539 and 540.

Figure 19 shows a method of wirelessly connecting the computer, in the form of a belt, to a Local Area Network (LAN). An infra-red transceiver 541, such as a Photonics Infra-red Transceiver, is functionally connected to the computer via a tether 542. The transceiver communicates via infra-red pulses with a plurality of infra-red repeaters 543 mounted overhead in the environment. Wireless communication could also be of radio-frequency type in which case the computer receiver would be included as a disintegrated module as shown in Figure 15.

In Figure 20, the configuration is the same as Figure 3, but instead of a hardwired connection, both the computer and pen-based display device 60 have wireless infra-red pulse transceivers 544 and 545. The pen-based display 60 sends pen location data to the computer and the computer sends  
5 corresponding graphical information to the pen-based device 60.

Figure 21 demonstrates a wireless infra-red communication link between a Private Eye heads-up display 538 and the computer. An infra-red receiver 546 is located on the heads-up display. An infra-red transceiver 547 is located in the shoulder area of the computer.

10 In Figure 22, an LCD projection display 548 is mounted on the front abdominal area of the computer, which is in the form of a vest. This device works by projecting a strong light through an LCD that is controlled by a computer, and then through a focusing lens. The LCD projection display 548 projects a computer generated image of any reflective, flat  
15 surface, such as a reflection pad 548' hanging from the user's waist, or the user's palm. To view the computer's output, the user would hold up the reflection pad 548' or the palm in the path of the image that is being projected. The image is reflected and thus readable to the user.

Figure 23 shows the wearable computer system in the form of a  
20 headband 549 with an attached heads-up display 538.

Figure 24 shows the computer in the form of a belt with a split QWERTY keyboard 550 attached to the computer so that it hangs downward in front of the user and can be easily reached. The user types in commands just as he would at a desk top keyboard.

25 Figure 25 shows the computer implemented as a flexible form that wraps around the forearm. The user interface consists of a keypad 551 and speech recognition and speech synthesis capability. A microphone 552 and speaker 553 are included in the computer.

Figure 26 shows the computer in the form of a vest with a Private  
30 Eye heads-up display 554 mounted on the left breast. To access the graphical output of the computer, the user looks down and to the left into the heads-up display 554.

Figure 27 shows the computer in the form of a vest with an ear clip microphone/speaker device 555. The method of controlling the computer is speech recognition. The output from the computer to the wearer is speech synthesis. This configuration allows only the wearer to hear the output from the computer, and to speak at low volumes when inputting commands.

Figure 28 shows the computer in the form of a garment with motion sensors 556a, 556b, 556c, 556d, 556e and 556f. The computer continually polls these sensors. The data from these sensors is used by the computer as input to drive software that would interpret the data from the sensors as certain gestures. These gestures can be used to control the computer. For example, the user may be able to switch the computer into a mode where it is listening for the wearer's voice input simply by making a circular motion with the left arm. A circular motion in the opposite direction would switch off the listen mode.

Figure 29 illustrates the invention in a totally hands-free operation. The computer is in vest form and incorporates a speech recognition and/or speech synthesis interface including a microphone 557 and a speaker 558. In this configuration, the need for rigid interface hardware such as keyboards or liquid crystal displays is obviated.

Many of the various interface peripherals can be used in combination with each other. For example, the arm mounted flexible LCD shown in Figure 17 could be used as the output device and voice recognition could be used as the input device. Or, referring to Figure 25, the flexible wearable computer worn on the forearm could be controlled with voice recognition.

Thus the scope of the invention should be determined by the appended claims and their legal equivalents, rather than by the examples given.

I CLAIM:

CLAIMS

- 1 1. A portable computer comprising, in combination, elements for  
2 computing comprising:  
3 input means for inputting data;  
4 output means for outputting data, and  
5 a plurality of computing components;  
6 a flexible non-stretchable human wearable member;  
7 means for rigidly mounting said computing elements on said  
8 wearable member; and  
9 flexible signal relaying means electrically connecting said  
10 computing elements, the length of said relaying means between any  
11 two of said computing elements being greater than the length of  
12 said wearable member between said any two computing elements.
- 1 2. The computer of claim 1 including certain elements in the form of a  
2 belt.
- 1 3. The computer of claim 1 including certain elements in the form of a  
2 sleeve.
- 1 4. The computer of claim 1 including certain elements in the form of a  
2 headband.
- 1 5. The computer of claim 1 including means for forming a free space  
2 pointer.
- 1 6. The computer of claim 1 including a heads-up display device.
- 1 7. The computer of claim 1 including a wireless communication link  
2 between said computing elements and one or more of said input means  
3 and said output means.



- 1 8. The computer of claim 1, wherein the output means comprises a  
2 touch-sensitive flexible LCD adapted to be worn on a user's forearm.
- 1 9. The computer of claim 6, further comprising a free space pointer  
2 linked to the heads-up display device.
- 1 10. The computer of claim 1, including connecting means for  
2 connecting the computer to a Local Area Network.
- 1 11. The computer of claim 10, wherein the connecting means  
2 comprises an infra-red transceiver for communicating with at least one  
3 infra-red repeater of the Local Area Network.
- 1 12. The computer of claim 1, wherein at least one of the input means  
2 and the output means includes a pen-based display device, the computer  
3 further comprising a wireless communication link between the display  
4 device and the computing elements.
- 1 13. The computer of claim 6, further comprising a wireless  
2 communication link between the heads-up display device and the  
3 computing elements.
- 1 14. The computer of claim 1, further comprising an LCD projection  
2 display linked to the computing elements, and a reflection pad positioned  
3 to reflect output of the display so as to be readable by a user of the  
4 computer.
- 1 15. The computer of claim 6, further comprising a headband coupled  
2 with the heads-up display device to support the heads-up display device  
3 on the head of a user of the computer.

1 16. The computer of claim 1, wherein the input means comprises a  
2 split keyboard.

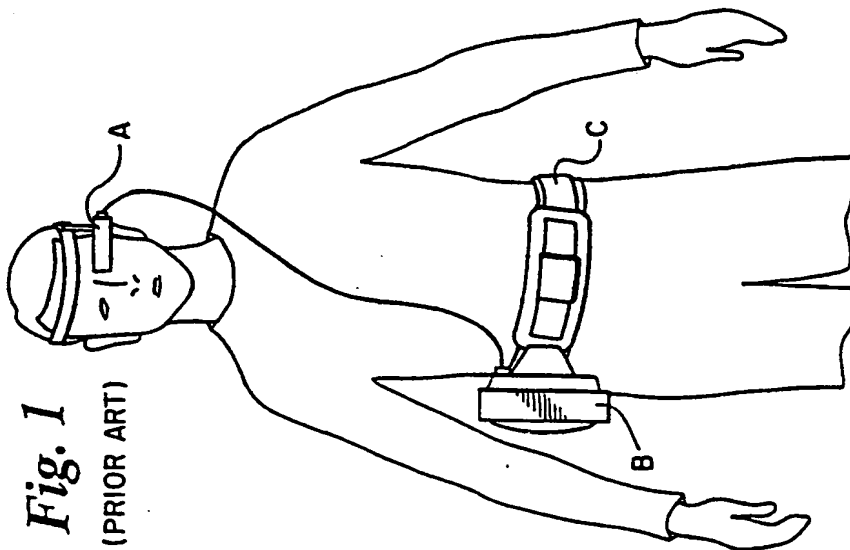
1 17. The computer of claim 1, wherein the computer is adapted to be  
2 supported on the forearm of a user, the computer further comprising a  
3 microphone, a speaker, and a user interface with speech recognition and  
4 speech synthesis capability.

1 18. The computer of claim 6, further comprising a vest supporting the  
2 heads-up display device below the head of an operator of the computer.

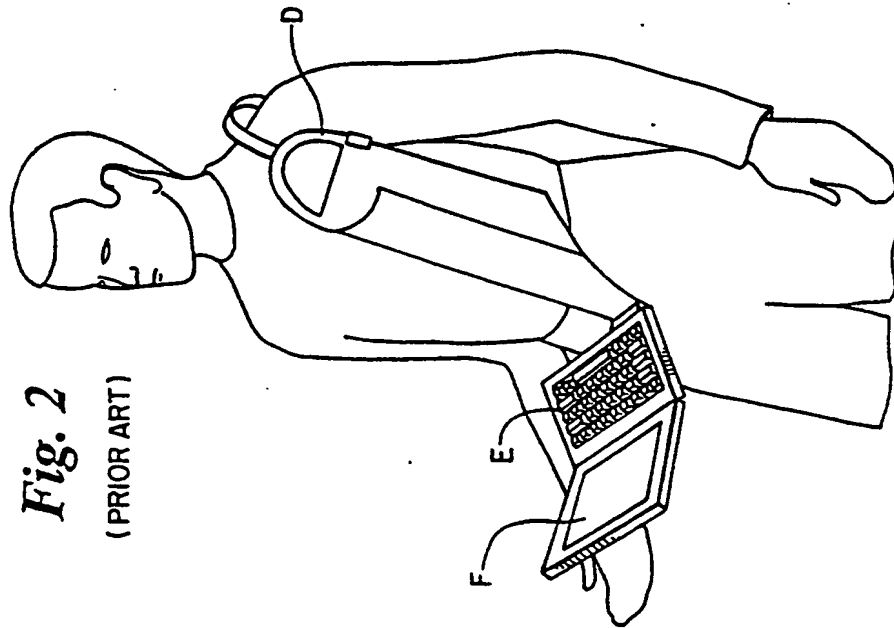
1 19. The computer of claim 1, further comprising a microphone/speaker  
2 device for speech input and output.

1 20. The computer of claim 1, further comprising a garment with  
2 motion sensors coupled with the computing elements to input data to the  
3 computer.

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**Fig. 1**  
(PRIOR ART)



**Fig. 2**  
(PRIOR ART)

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Fig. 4

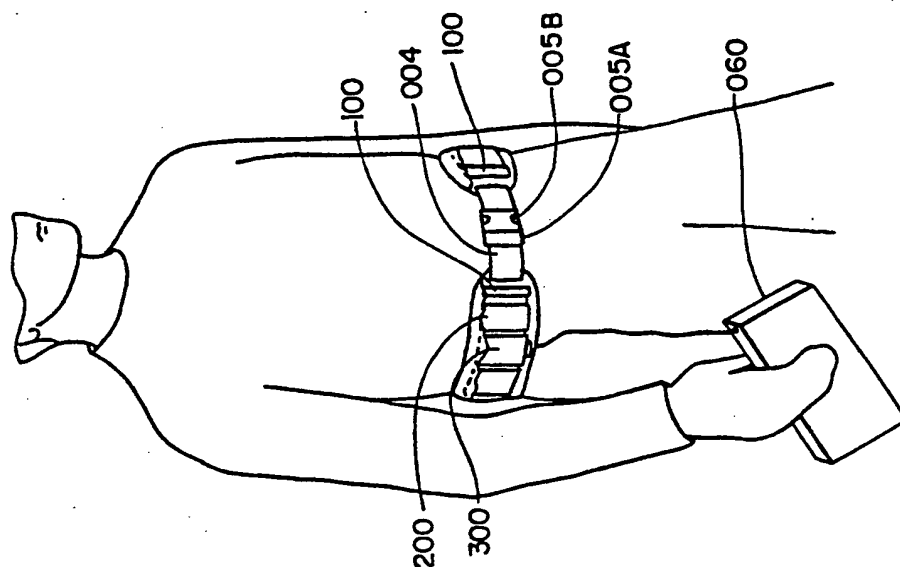
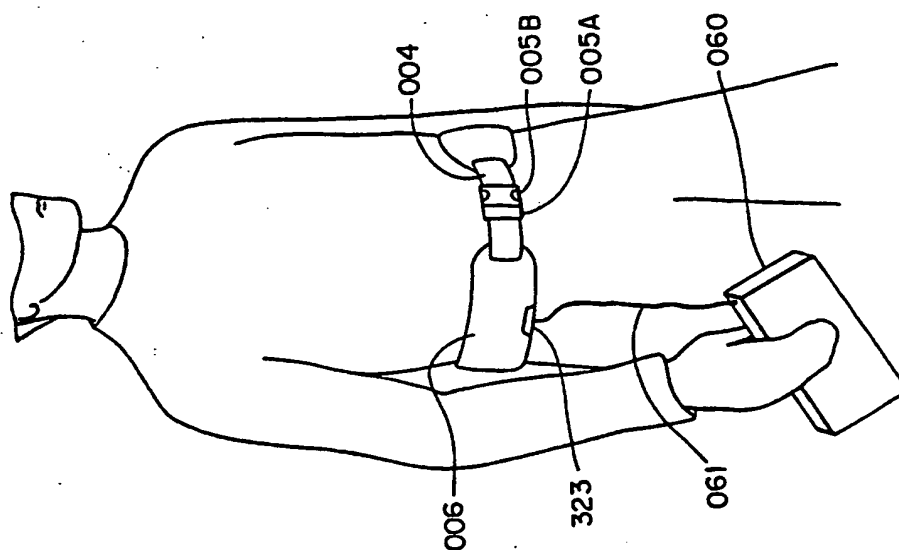


Fig. 3



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Fig. 5

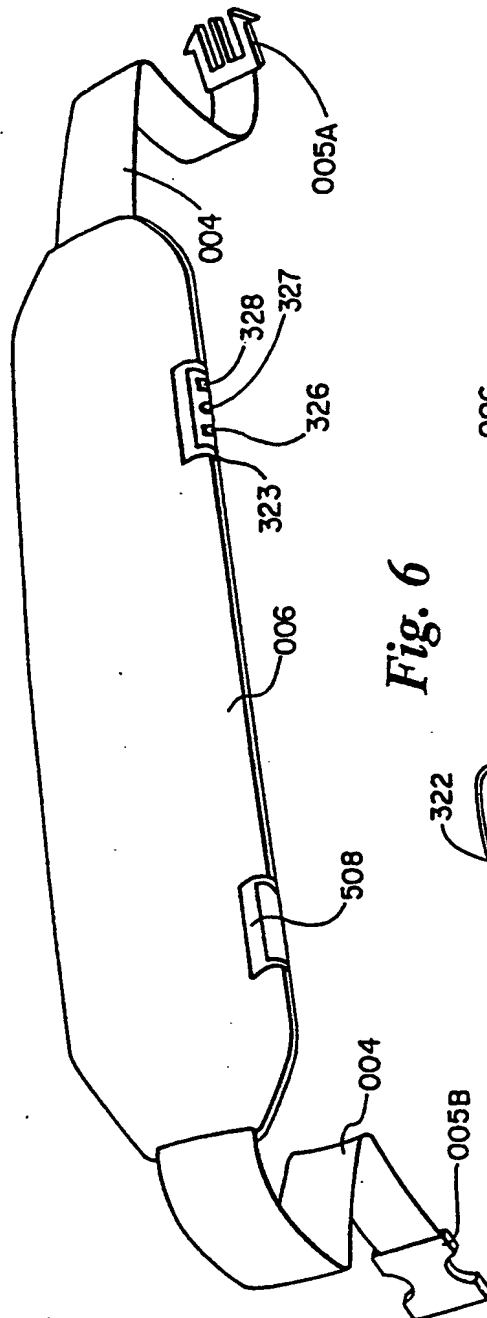
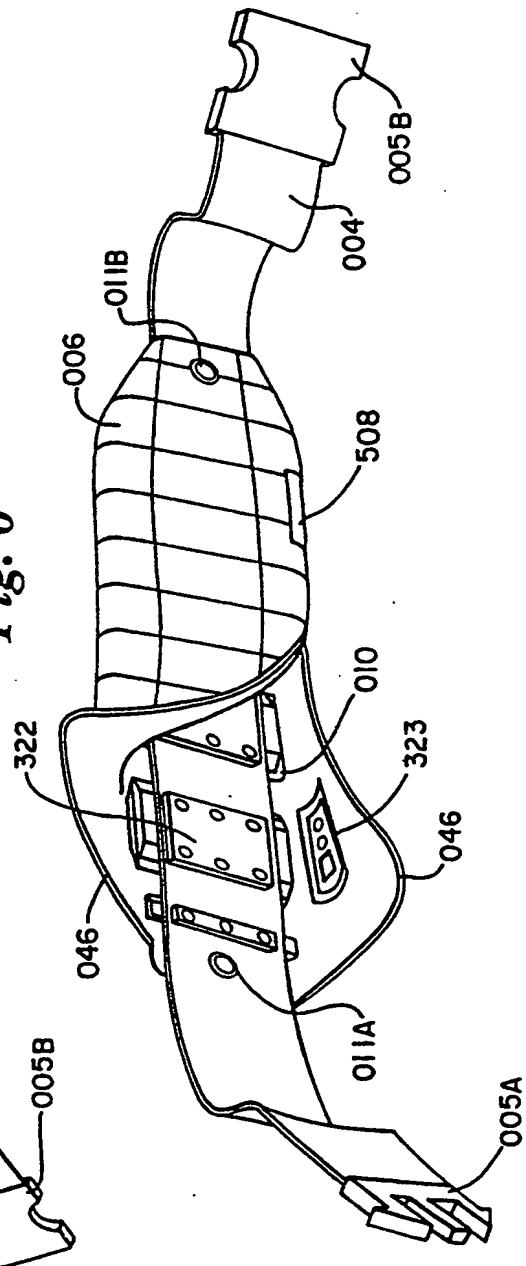


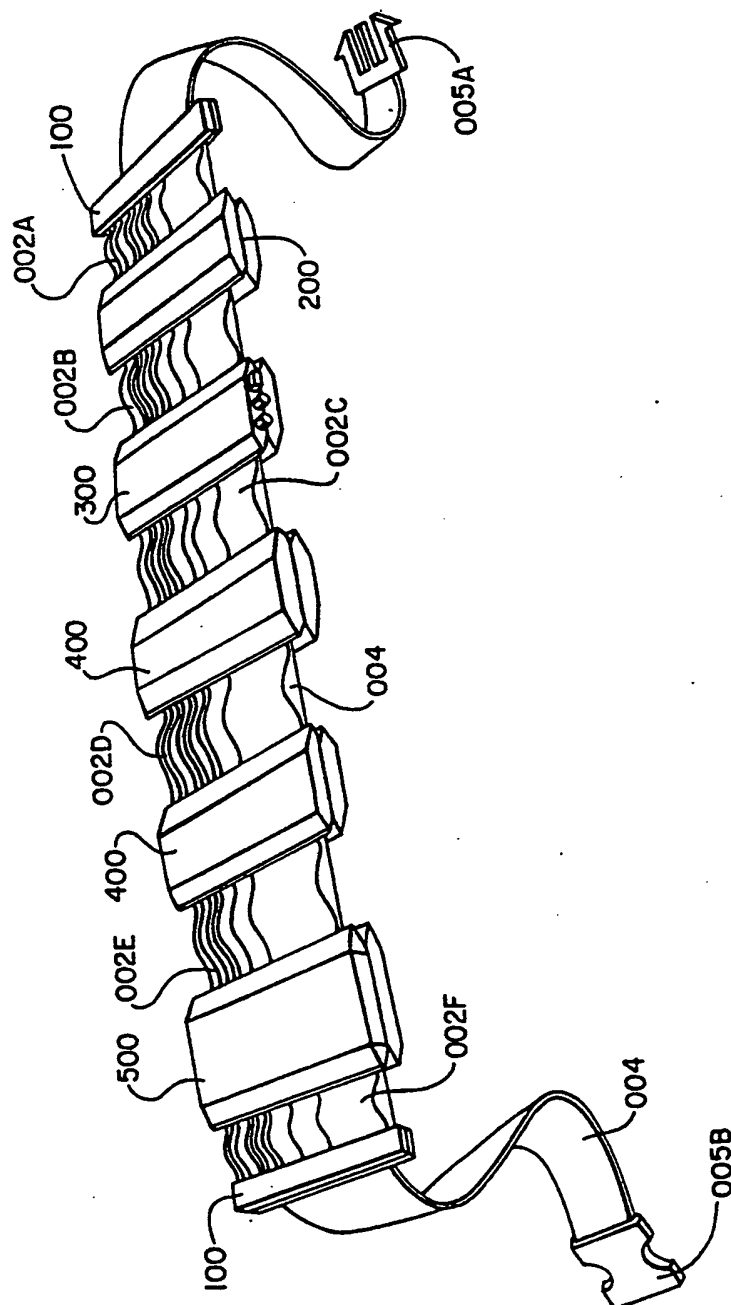
Fig. 6



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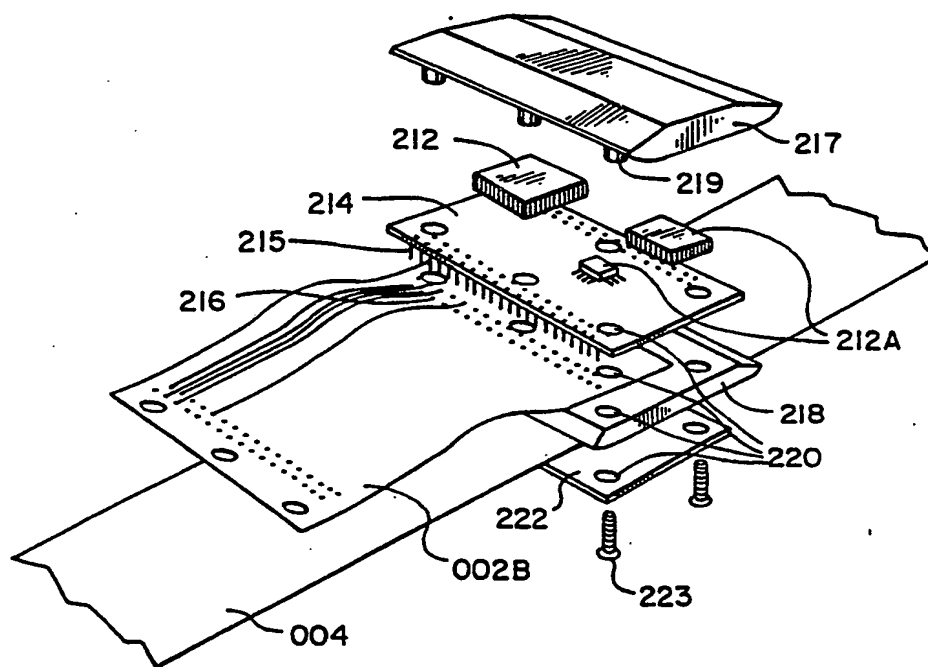
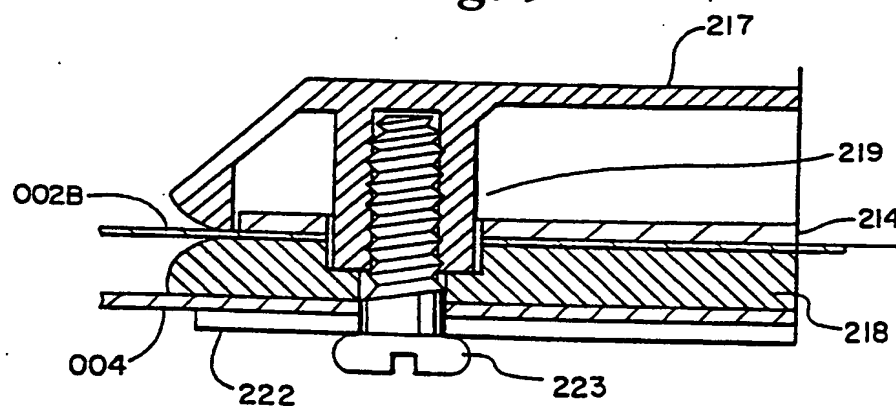
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Fig. 7



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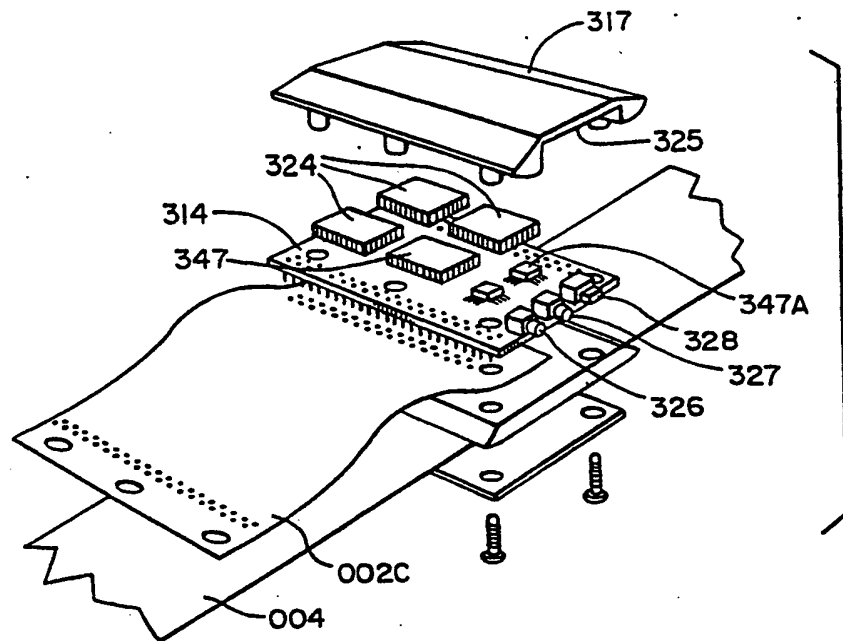
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*Fig. 8**Fig. 9*

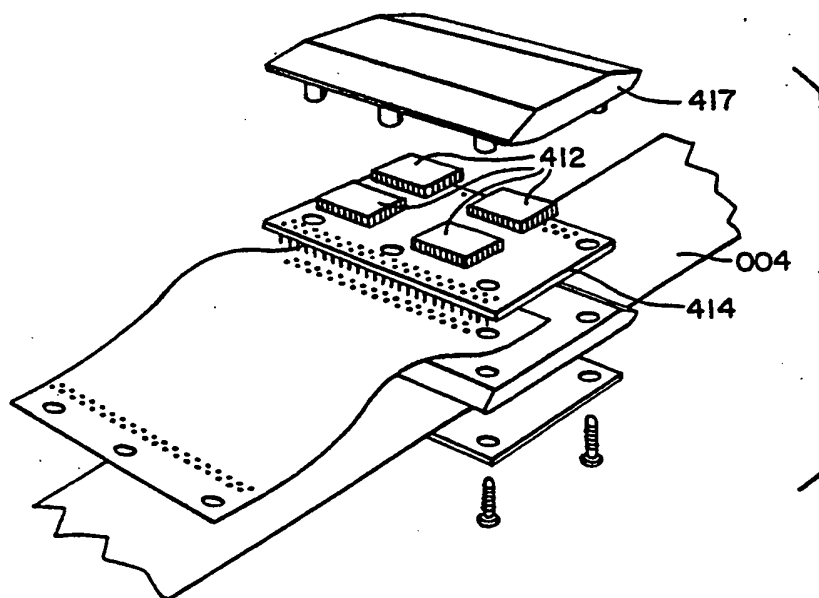
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*Fig. 10*



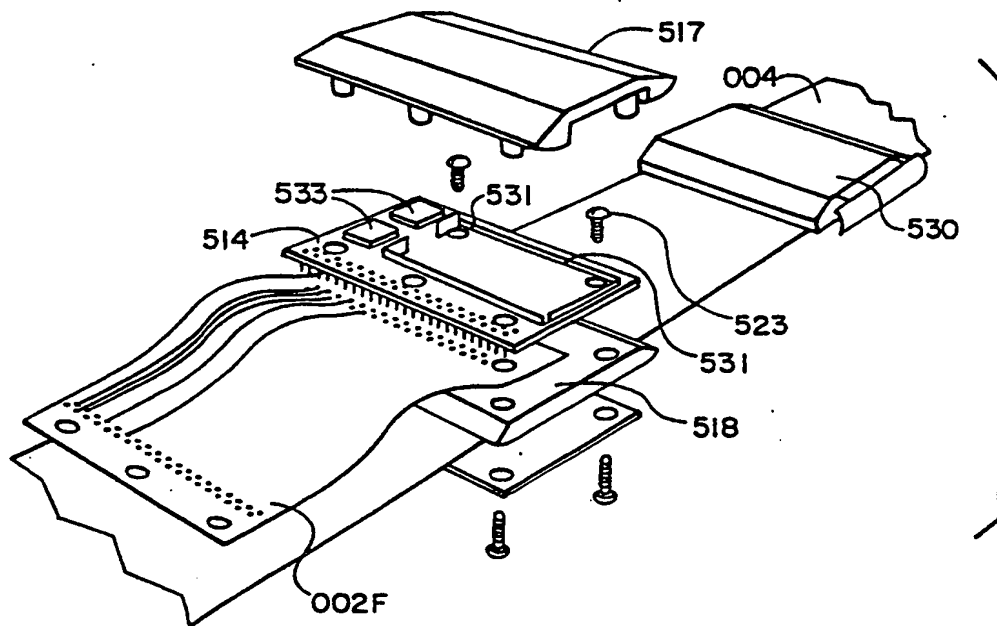
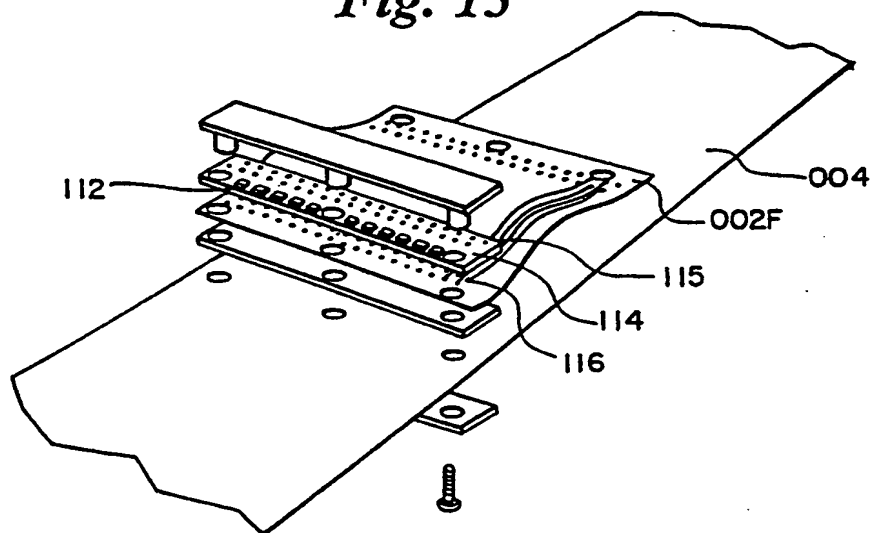
*Fig. 11*



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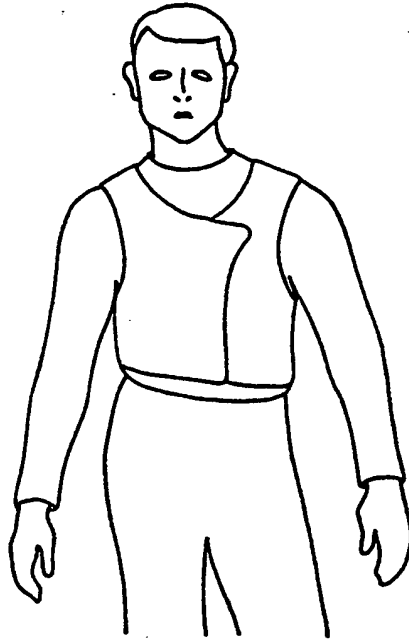
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*Fig. 12**Fig. 13*

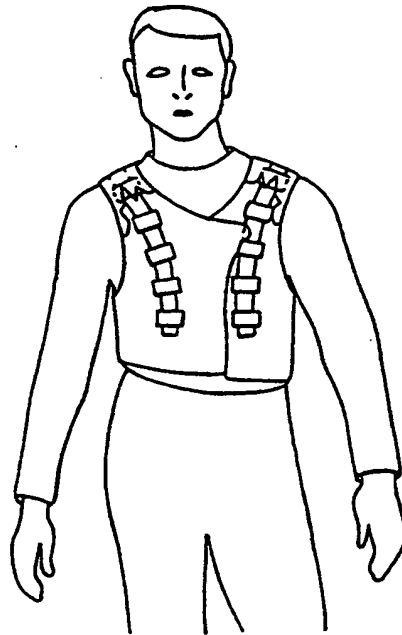
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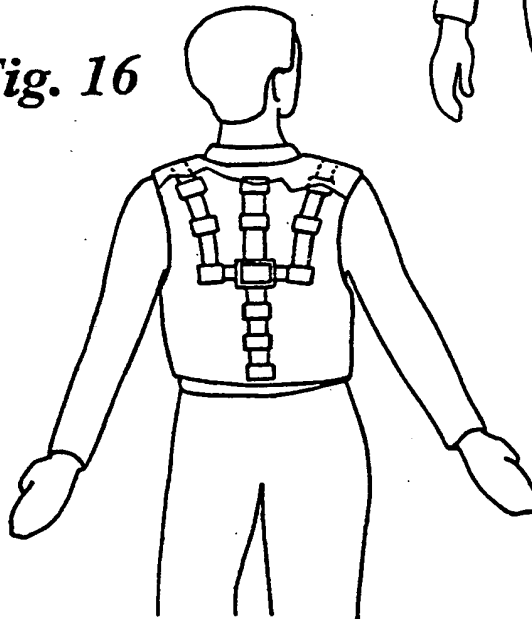
*Fig. 14*



*Fig. 15*



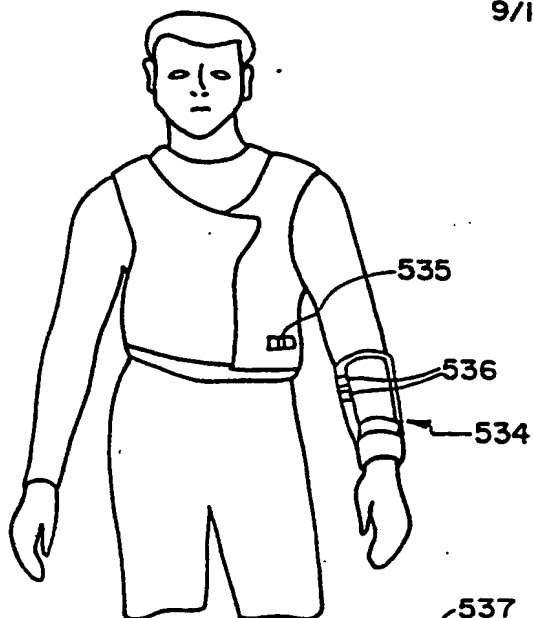
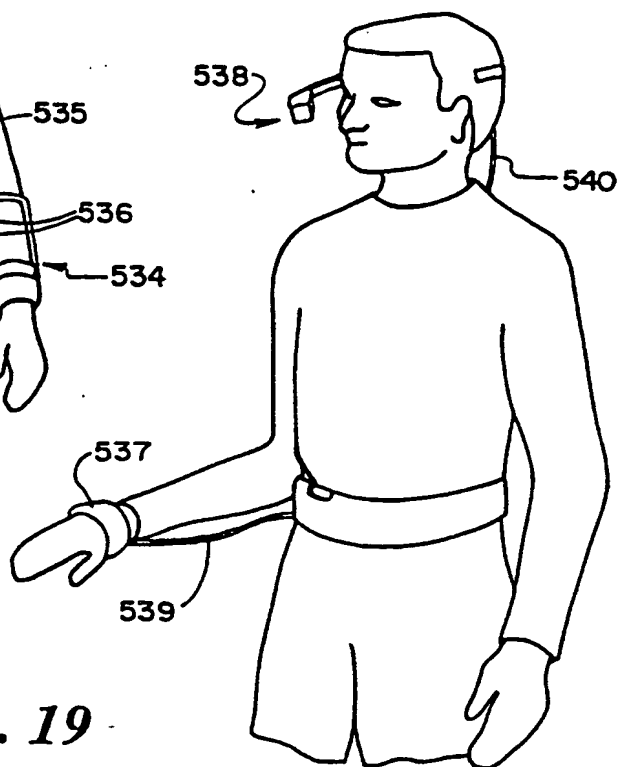
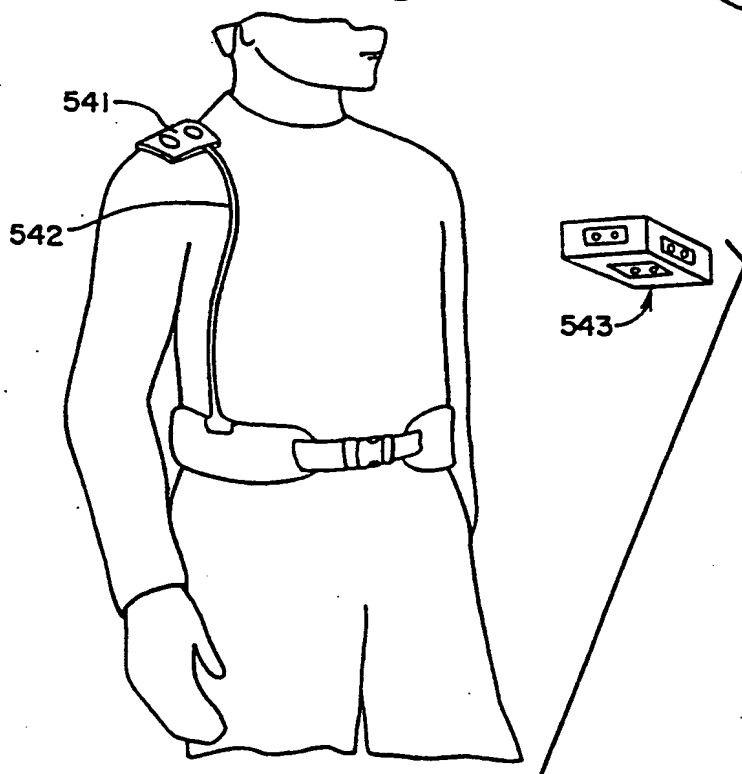
*Fig. 16*



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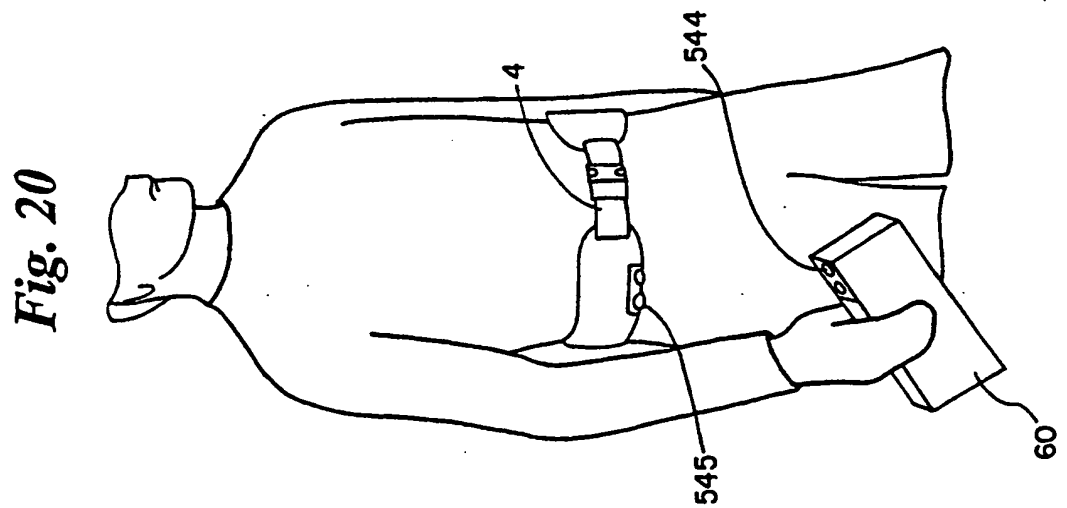
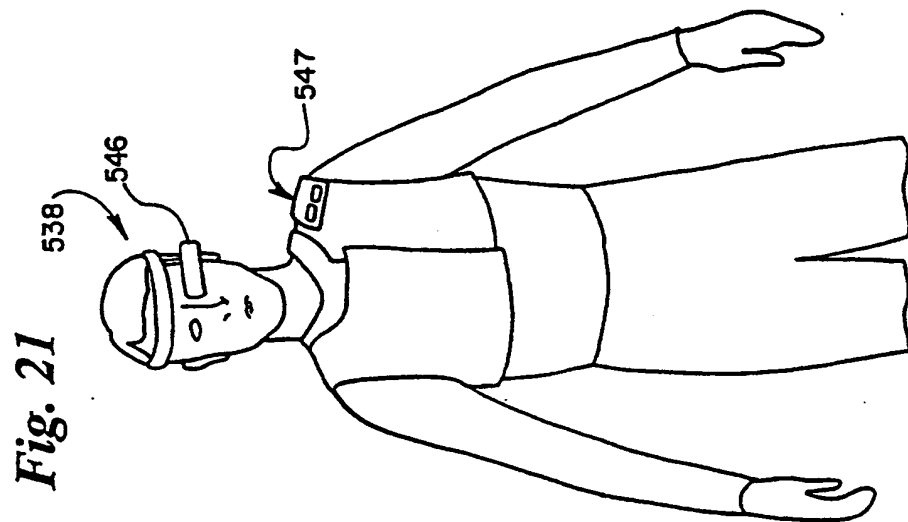
**Fig. 17**

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**Fig. 18****Fig. 19**

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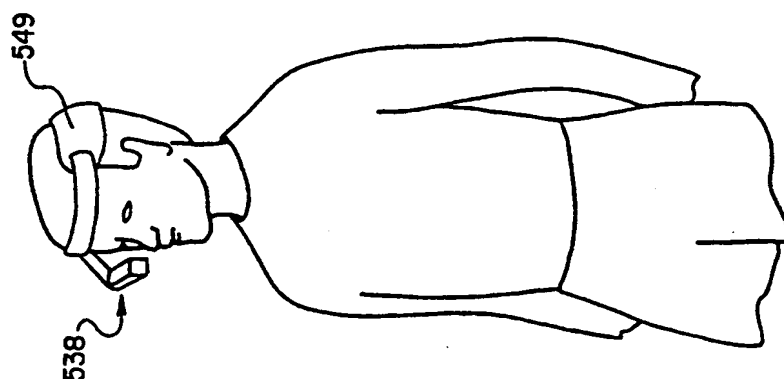
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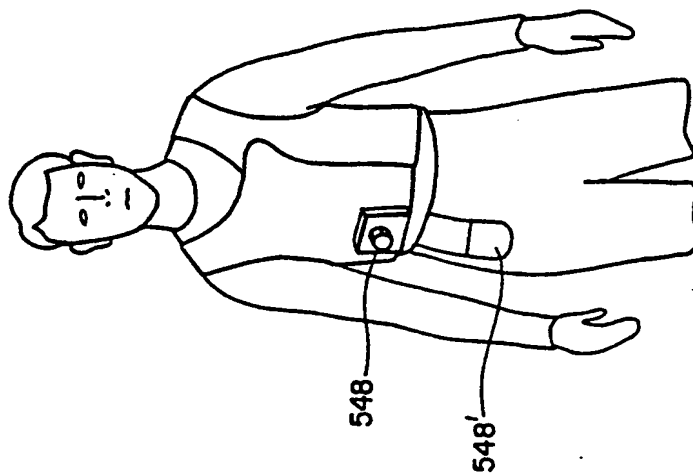
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**Fig. 23**



**Fig. 22**



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Fig. 25

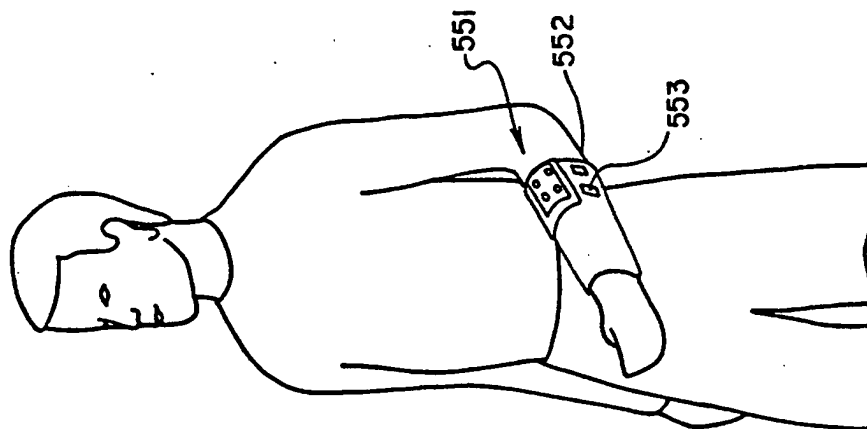
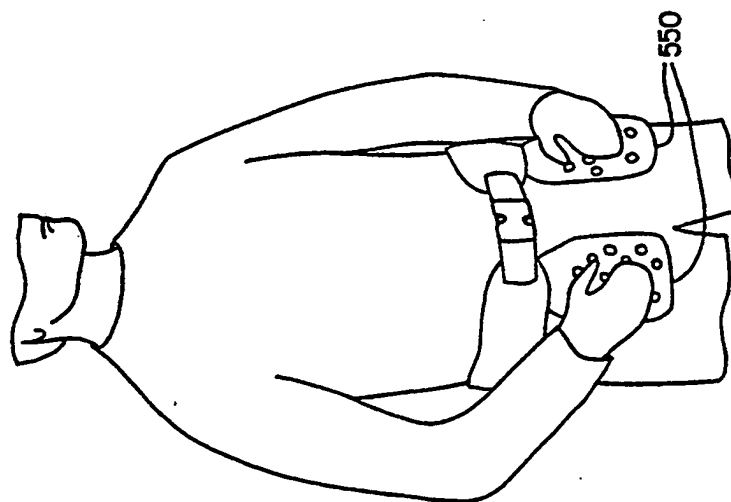


Fig. 24



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Fig. 27

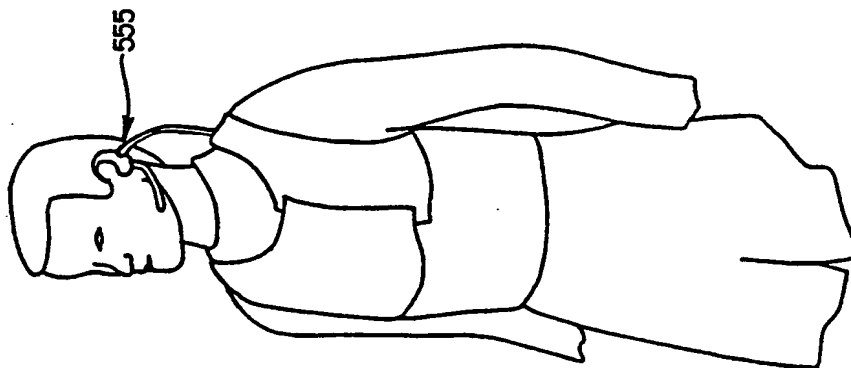
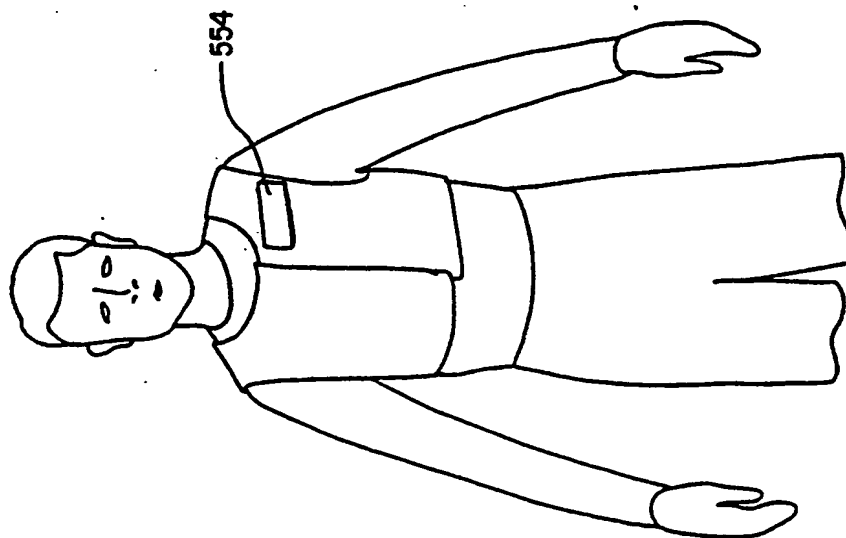


Fig. 26



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Fig. 29

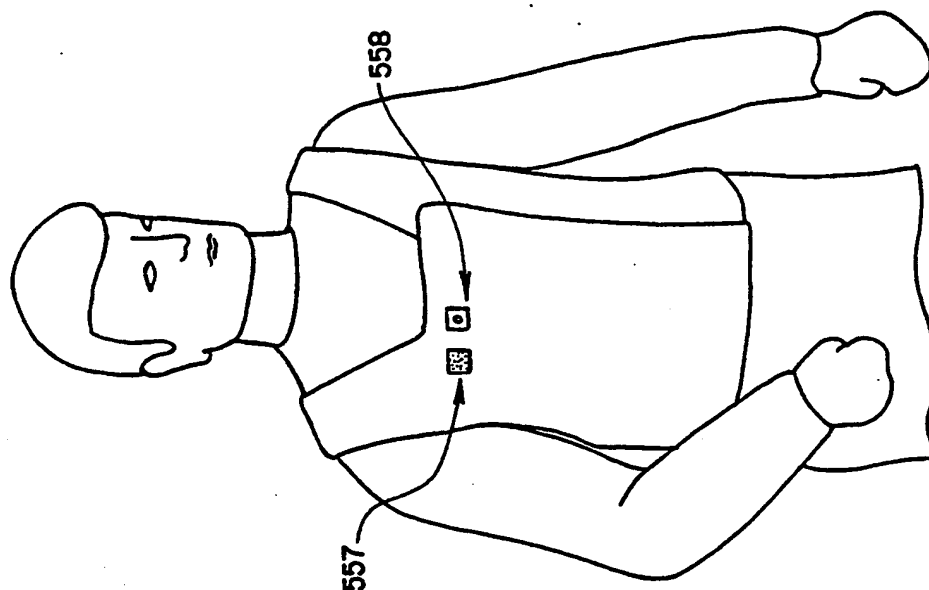
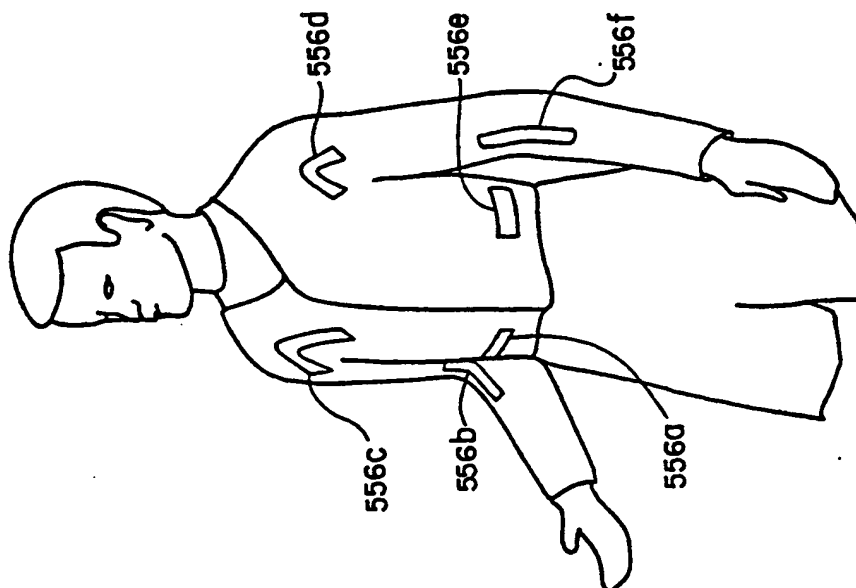


Fig. 28





## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US95/01630

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : Please See Extra Sheet.

US CL : 364/708.1; 361/394, 398; 128/420.5, 421; 219/497

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 364/708.1; 361/394, 398; 128/420.5, 421; 219/497

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
APS

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category <sup>a</sup>	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y,P	US, A, 5,285,398 (JANIK) 08 FEBRUARY 1994 SEE ENTIRE DOCUMENT	1-20
A	US, A, 5,078,134 (HEILMAN ET AL) 07 JANUARY 1992	1-20
A	US, A, 5,267,181 (GEORGE) 30 NOVEMBER 1993	1-20
A	US, A, 5,029,260 (ROLLASON) 02 JULY 1991	1-20
A	US, A, 5,035,242 (FRANKLIN ET AL) 30 JULY 1991	1-20

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

<sup>a</sup> Special categories of cited documents:	<sup>T</sup> later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principles or theory underlying the invention
<sup>A</sup> document defining the general state of the art which is not considered to be part of particular relevance	<sup>X</sup> document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
<sup>E</sup> earlier document published on or after the international filing date	<sup>Y</sup> document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
<sup>L</sup> document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (to be specified)	<sup>Z</sup> document member of the same patent family
<sup>O</sup> document referring to an oral disclosure, use, exhibition or other means	
<sup>P</sup> document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

04 MAY 1995

Date of mailing of the international search report

22 JUN 1995

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Form PCT/ISA/210 (second sheet)(July 1992)\*

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US95/01630

## A. CLASSIFICATION OF SUBJECT MATTER: IPC (6):

G06F 1/00; H05K 5/00